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Optical microscopy and its contribution to the control of applied submerged entry nozzle (SEN) in continuous casting of steel

The aim of this paper is to represent results of optical microscopy in control of Submerged Entry Nozzle (SEN) that will show the contribution of this method in the process of continuous casting of steel. A large number of SEN have been monitored and tested in the long period. This paper shows the most interesting results. SEN are formed parts of refractory materials based on alumina-graphite. They are produced with isostatic pressing process and used in all kinds of steel casting. A polarizing microscope Neophot 32 was used for examination with optical microscopy (reflected light) method. In the process of continuous casting of steel, SEN is in contact with steel and casting powder that can act destructively on SEN. Thus, SEN erosion is the result of that destruction. Steel effects on the inner wall of SEN, while casting powder effects on the outside of the wall. The destructive effect of steel and casting powder reduces the durability and resistance of SEN. Micrographs in this paper present the appearance and structure formed at the contact of steel - wall of SEN and casting powder - wall of SEN. Appearance, structure and minerals as a result of optical microscopy examination indicate the influence of various factors on the process of continuous steel casting. These factors are the quality of casting powder, the quality of SEN, technological parameters (speed of steel casting, casting temperature, composition of the steel) and others. Depending on the obtained SEN results, if necessary, the correction of technology parameters and other influencing factors could be performed. The correction depends on the causes for SEN resistance reduction. Thus, if external SEN erosion is large, a less aggressive casting powder will be used in the process.The results of optical micrscopy in control SEN indirectly contribute to improving processes, increasing quality of the final products and reduce costs.

***Key words**: optical microscopy, SEN, casting powder,steel, continuous casting*

1. INTRODUCTION

Outlet refractory material is used during the process of continuous steel casting. Those are formed parts of refractory materials and each part has a specific function in the process of continuous casting [1]. Submerged entry nozzle (SEN) is one of them. Its function is to provide safe steel casting from a tundish into crystallizer, but also to protect the steel from contact with oxygen, since the inner side is in contact with the steel. Steel has weak or strong affect and leads to SEN erosion [2]. Sometimes this causes the chemical reaction on that contact and formation of scab [3]. Scab(alumina build – up, or inner SEN deposits) reduces outlet hole of SEN and the flow of steel. Scab composition usually consists of secondary corundum, hibonite, hibonite -5H, steel inclusions and others [4].

Melting temperature of formed minerals in the scab are higher than steel casting temperature. On the outside SEN is in contact with the casting powder. Casting powder is sprinkled on the surface steel mold. One of the most important functions of casting powder is to protect steel from oxidation and to prevent formation of non-metallic inclusions in steel. Non-metallic inclusions are the most common causes of errors and poor steel quality. However, casting powder also has an unwanted effect. There are reactions at the contact of the SEN wall and casting powder that cause erosion [5]. Casting powder slowly melts and turns into the slag on the casting temperature which is about 1558^0C. Slag can be more or less aggressive depending on the composition of the casting powder [6,7 and 8].

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2. EXPERIMENTAL PART

The experimental part of this research included testing a large number of SEN samples using optical microscopy method. Microscopic examinations (reflected light)were performed at the microscope

Neophot 32. Selected results: micrographs presented in the paper show the appearance, structure and mineral composition of SEN after the exploitation. During SEN control and based on the results of optical microscopy, causes of reduced lifetime of SEN can be determined.

3. RESULTS AND DISCUSSION

Results obtained during SEN control using optical microscopy method showed different structures that have been formed in contact with the casting powder. These differences are caused by a weaker or stronger external SEN erosion. Figures 1, 2 and 3 are micrographs of outside wall of SEN and present preserved structure of SEN. No significant changes in the structure. The graphite in the form of strips and grains of corundum as main minerals are present. Grouping of graphite tape and less presence of glassy phase are noticeable. During the SEN exploitation, less aggressive powders are used which caused longer lifetime of SEN.

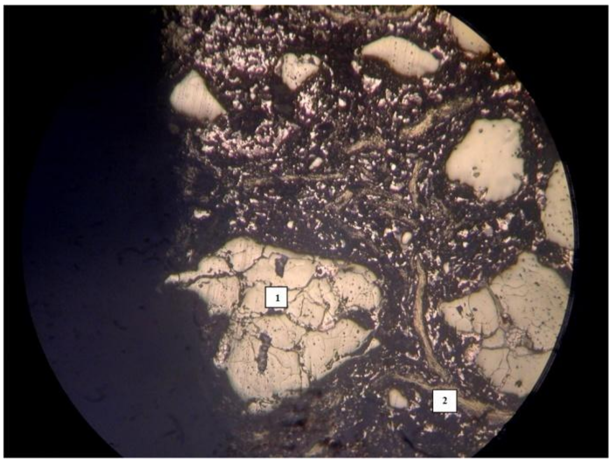

Figure 1 - Micrograph of the structure of SEN after the exploitation(magnification of 250x); 1- primary corundum,2-strips of graphite

Aggressive casting powder and slag penetrated and destroyed the structure of SEN. Glassy slag penetrated between the corundum grains and graphite strips. Chemical reactions at the contact between slag and wall of SEN sometimes cause formation of spinels. Formed spinels and glassy slag are in composition of the outer scab. Figures 4, 5, 6 and 7 show the penetration of glassy slag into the structure of SEN and the destruction of the structure.

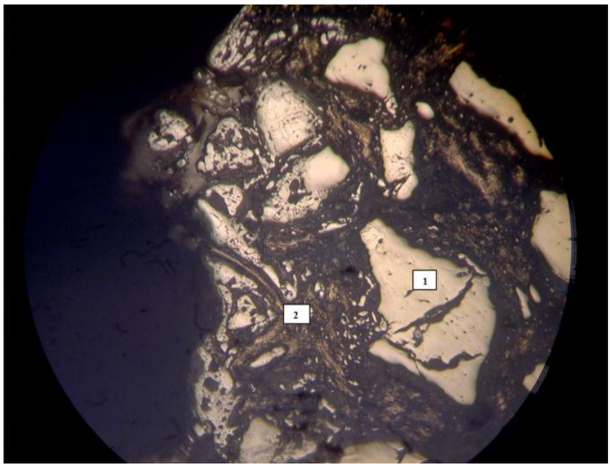

Figure 2 - Micrograph of the structure of SEN after the exploitation(magnification of 250x); 1- grains of primary corundum;2- strips of graphite

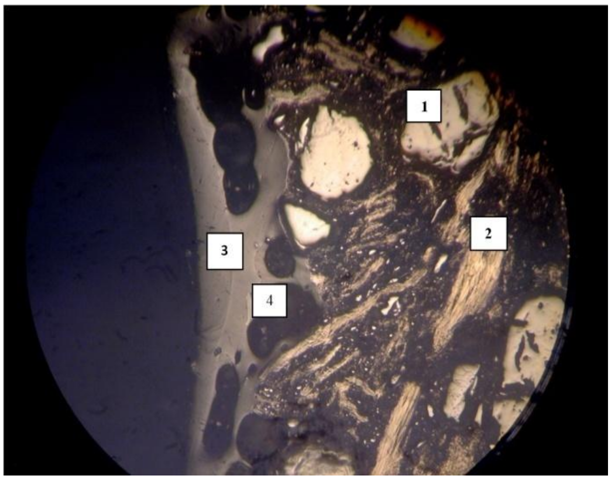

Figure 3 - Micrograph of the structure of SEN after the exploitation(magnification of 250x);1 primary corundum,2- graphite,3-slag,4-hole

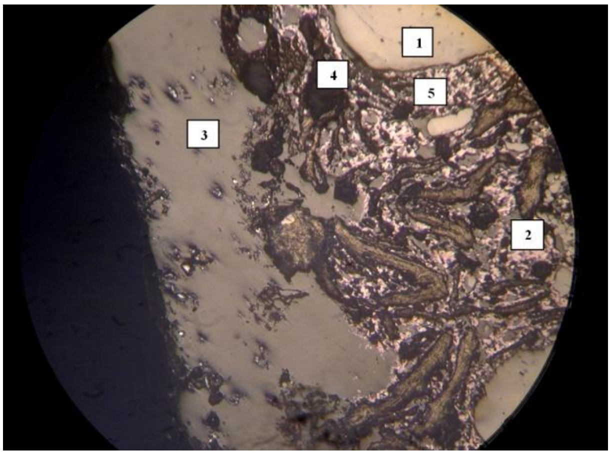

Figure 4 - Micrograph of the structure of SEN after the exploitation(magnification of 250x);1- primary corundum,2- graphite,3- glassy slag, 4-hole, 5-spinels

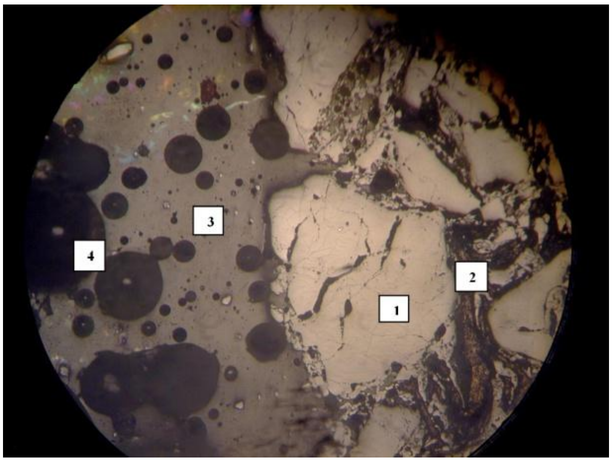

Figure 5 - Micrograph of the structure of SEN after the exploitation(magnification of 250x); 1- primary corundum,2- graphite,3- slag,4-hole

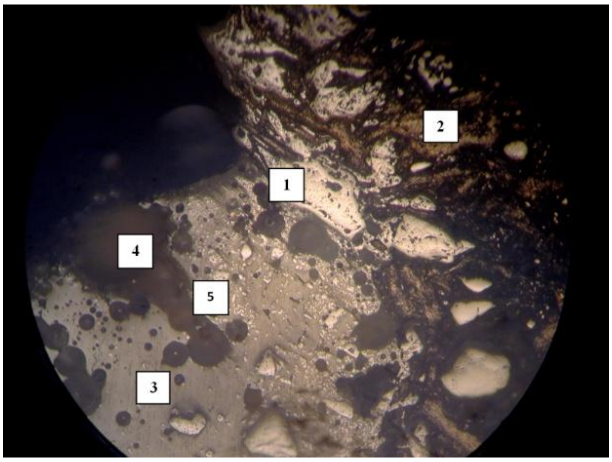

Figure 6 - Micrograph of the structure of SEN after the exploitation(magnification of 250x); 1-primary corundum,2- graphite,3- glassy slag, 4-hole 5- spinels

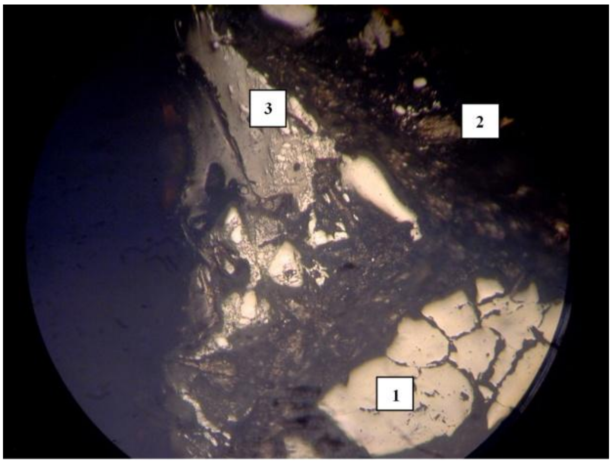

Figure 7 - Micrograph of the structure of SEN after the exploitation(magnification of 250x); 1- primary corundum, 2- graphite, 3 - spinels with slag

4. CONCLUSION

Results showed that optical microscopy is very important for the control of nozzle and the process of continuous steel casting. Microscopic examination can easily determine reasons that cause changes in the nozzle structure. Appearance, structure and minerals present in SEN and in the contact with the slag and steel indicate significant factors that need to be corrected. The contribution of optical microscopy is the ability to timely correct important factors in the process of continuous casting. Corrections are related to:

- Usage of less aggressive casting powder in the process
- Usage of SEN with better performance (quality and design)
- Adjustment of technological parameters in continuous casting process
- Sort and composition of the steel
- Adjustment of steel deoxidation and reoxidation process
- and others.

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IZVOD

OPTIČKA MIKROSKOPIJA I NJEN DOPRINOS KOD KONTROLE IZLIVNIKA PRIMENJENIH U PROCESU KONTINUIRANOG LIVENJA ČELIKA

Cilj rada je da prikaže pojedine rezultate primene Optičke mikroskopije u kontroli uronjavajucih izlivnika (SEN). Istovremeno da ukaže na doprinos ove metode u procesu kontinuiranog livenja čelika. U dužem vremenskom periodu praćen je i ispitan veliki broj izlivnika. U radu su prikazani najinteresantniji rezultati. Ispitani SEN su oblikovani delovi od vatrostalnog materijali na bazi alumografita (Al_2O_3-C) proizvedeni izostatičkim presovanjem. Primenjuju se pri livenju svih vrsta čelika. Za ispitivanja metodom Optičke mikroskopije korišćen je polarizacioni mikroskop Neophot 32 i odbijena svetlost. SEN u toku odvijanja procesa kontinuiranog livenja delom je uronjen u čelik koji se nalazi u kristalizatoru. U kristalizatoru SEN je u kontaktu sa čelikom, ali i sa livnim prahom koji je posut po čeliku radi zaštite čelika od oksidacije. I čelik i livni prah destruktivno dejstvuju na SEN, te dolazi do pojave erozije zida SEN. Čelik dejstvuje na unutrašnju stranu zida SEN, dok livni prah na spoljašnju stranu zida. Destruktivno dejstvo čelika i livnog praha smanjuje vek trajanja SEN, to jest njegovu izdržljivost. U ovom radu prikazane su mikrofotografije izgleda i strukture nastale na kontaktu čelik – zid SEN i kontaktu livni prah – zid SEN. Izgled, struktura i minerali kao rezultat ispitivanja optičkom mikroskopijom ukazuju na uticaje pojedinih faktora na proces kontinuiranog livenja čelika. Ti faktori se odnose na kvalitet livnog praha, kvalitet SEN, prvilno odabrane tehnološke parametre kao što su brzina livenja, temperatura livenja, odgovarajući sastav čelika i dr. Na osnovu dobijenih rezultata ispitivanja SEN, ako je potrebno može se vršiti korekcija u vodjenju procesa. Ta korekcija se vrši i zavisi od uzroka smanjenja veka trajanja SEN. Tako ako je velika spoljašnja erozija SEN pristupa se uvodjenju u proces manje agresivanog livnog preha. Rezultati optičke mikroskopije pri kontroli SEN indirektno doprinose poboljšanju procesa, povećanju kvaliteta finalnog prozvoda i smanjenju troškova.

Ključne reči: *optička mikroskopija,uronjavajući izlivnik,livni prah,čelik, kontinuirano livenje*

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